UCD Impact Case Study

Making Building on Sand a Realistic Option

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ECONOMIC TECHNOLOGICAL ACADEMIC ENVIRONMENTAL

SUMMARY

In the Bible Saint Mathew warns of "the foolish man who built his house on sand". Dr Michael Long and his colleagues at the UCD-based, Science Foundation Ireland-funded Irish Center for Research and Applied Geoscience (iCRAG) are hoping that a project they have recently commenced will overcome such uncertainty. The project explores the potential use of a relatively new approach to ground improvement, making use of either bacteria or enzymes to accelerate the natural process of cementation between grains of sand to increase their strength and load bearing capacity. This approach would be significantly more ecologically acceptable than current methods of ground improvement. As well as testing the technique to determine its effectiveness on local Irish soils, the researchers also intend to develop an appropriate testing regime to ensure compliance with Eurocode 7 requirements for building foundations.

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Approach to Ground Remediation

In engineering terms, weak or soft ground can typically be improved by introducing a mix of cement or lime into the ground, compacting the ground using large rollers or, in some instances improving drainage. The first two are increasingly unacceptable in environmental terms because of their high levels of energy consumption. So iCRAG's aim is to develop a more environmentally friendly approach to ground improvement.

The project, a "Multi-Scale Investigation of Bio-based Mineral Precipitation in Carbonate Bearing Granular Soils and Construction Related Waste," seeks to explore ways in which microbially induced carbonate precipitation (MICAP) and enzyme induced carbonate precipitation (ECIP) can be used as ground improvement technologies by cementing grains of sand together to create a strong foundation for building activity. Limestone, which is abundant in Ireland, contains calcite. This is in the sand and reacts with bacteria injected into it, accelerating the natural geological cementation process by effectively building calcite bridges between the grains, making the sand stronger and stiffer.

The technology behind this approach has been explored by researchers in a few other countries over the past five to 10 years, most particularly in the US, but has never been applied before in Ireland. The research, which is in its first year, is expected to take approximately four to five years to complete.

Blessington Quarry Research Site Location

As Dr Long explains: "Sand is loose because the grains are not cemented together. If you leave them for long enough, they will eventually turn into sandstone. The purpose of this project is to see if we can accelerate that cementation process by introducing a calcite, calcium carbonate, into the environment to glue the particles together. What we're talking about,for example, is growing calcite between the really tiny sand grains. The sand will then be stronger, allowing you to construct heavier buildings on it or make tunnels in it. The aim with foundations is to make ground immediately under the building stronger so it can support a greater load. This research is being done with my colleague Shane Donohue of the UCD School of Civil Engineering and Frank MacDermot, Professor of Geochemistry in UCD's School of Earth Sciences, whose earlier work on these chemical processes informs the current research. Researchers Christine Spencer and Maria Judge are also involved in this work.

Multiple Partners, Multidisciplinary Approach

To undertake this research, iCRAG, which is based in UCD but also has researchers in Trinity College Dublin (TCD), National University of Ireland Galway (NUIG) Galway and University College Cork (UCC), secured an SFI "Center to Centre" grant. The Energy Efficient Materials Research Centre at Queen's University Belfast (QUB) and centres at three universities in the US which are already engaged in research in this area – Arizona State University, Georgia Tech and the University of California, Davis – are also partners in the project. It is also highly interdisciplinary, involving engineers, geologists, geophysicists, chemists and contributions from other disciplines.

At the start of their work the iCRAG researchers identified a quarry in Blessington, Co Wicklow, as an appropriate research site. It has large deposits of sand that is representative of Western Europe and differs sufficiently from sands typically found in America to merit new research.

In phase one a student has worked full time on characterising the sand in terms of its various engineering properties, such as density, strength and stiffness, and on developing a fundamental understanding of the material itself, physically and under the microscope. The next step will be to introduce bacteria into the sand to accelerate the natural geological cementation process. A Postdoctoral Researcher has just joined the team and is working on this aspect of the project. That will start on a small scale, in a column maybe 50 millimeters diameter and 100 millimeters high, to be followed by increasingly larger scale tank sized experiments in the laboratory. It is hoped to eventually perform on site full-scale trials.

The strength of the treated sand will depend largely on how many injections have been put into it and part of the research is to identify the parameters involved in this process. "In this project we will have to ensure compliance with Eurocode 7, which dictates how safe a foundation should be, how much spare load capacity it should have and how much settlement is allowable. Typically a foundation might have to be designed to take 160 per cent of the actual load it will bear in real life, so as part of our research we will work out how many treatments are necessary to produce a strength adequate for Eurocode compliance. We also hope that by the end of this project we will have a good testing regime that could then be applied to any sands or soil. That's another deliverable for this project," Dr Long adds.

In addition to using bacteria the researchers will also follow the lead of their US counterparts in exploring alternative ways of stimulating this process using enzymes from plants. "We're hoping to develop a more environmentally friendly approach rather than using bacteria," Dr Long says. "The Americans have already done this on a much bigger scale and that's ultimately where we're going with this."

The QUB team is working on a closely related project, exploring the potential use of construction waste and applying similar technology to materials from demolished buildings that have been crushed into small particles. The US universities are interested in developing other ways of doing this treatment process, including ones not involving bacteria, to create more efficient ways of achieving the same end result. Furthermore, to date the US group have worked largely with silica sands and are keen to explore calcite bearing sands like those now being researched in Ireland.

Significant Potential Impacts

There is significant impact potential from this research by iCRAG which, as a center for applied science, seeks to help in the creation of jobs and the development of new techniques. Dr Long points to the proven effectiveness of the technique in a tunneling project in the Netherlands. “The hardest part of digging a tunnel is starting it, because the sand will simply collapse. So they stiffened up the sand at the entrance and then they were able to get their tunneling machine into the ground because it had a good, solid piece of ground with which to engage,” he points out.

In Ireland, as well as providing improved ground remediation for foundations this technique might also be useful in addressing the problem of small cracks and fissures in the ground caused by the action of water on limestone – what are known as karst problems. “Flooding in places like Gort in Co. Galway have been karst induced and buildings in Cork regularly have karst-related problems. So this process might be useful to improve the ground and prevent those problems arising,” Dr Long suggests. Nor is it only buildings that suffer from karst. Works on the M17 at Gort and N22 at Tralee, for example, were severely impacted by karst.

The new process will also help to reduce carbon emissions due by reducing the prevalence of or need for such high energy consuming and carbon producing activities as excavating and crushing and the manufacture and transportation of cement. This has the added benefit if also being much more economical than existing processes.

The project also has a Technical Advisory Committee (TAC) which keeps a watchful eye on what is being done. “This TAC will help us hone the research to ensure that it is practical and relevant,” Dr Long says. The TAC includes consultants, specialist contractors and main contractors as well as groups generally interested in eco-friendly construction solutions. “It is hoped that some of these companies can take our findings to expand their range of products and therefore create jobs and revenue for themselves, although the precise extent of that opportunity is not easy to quantify at this stage,” he adds.

Social & Media References

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